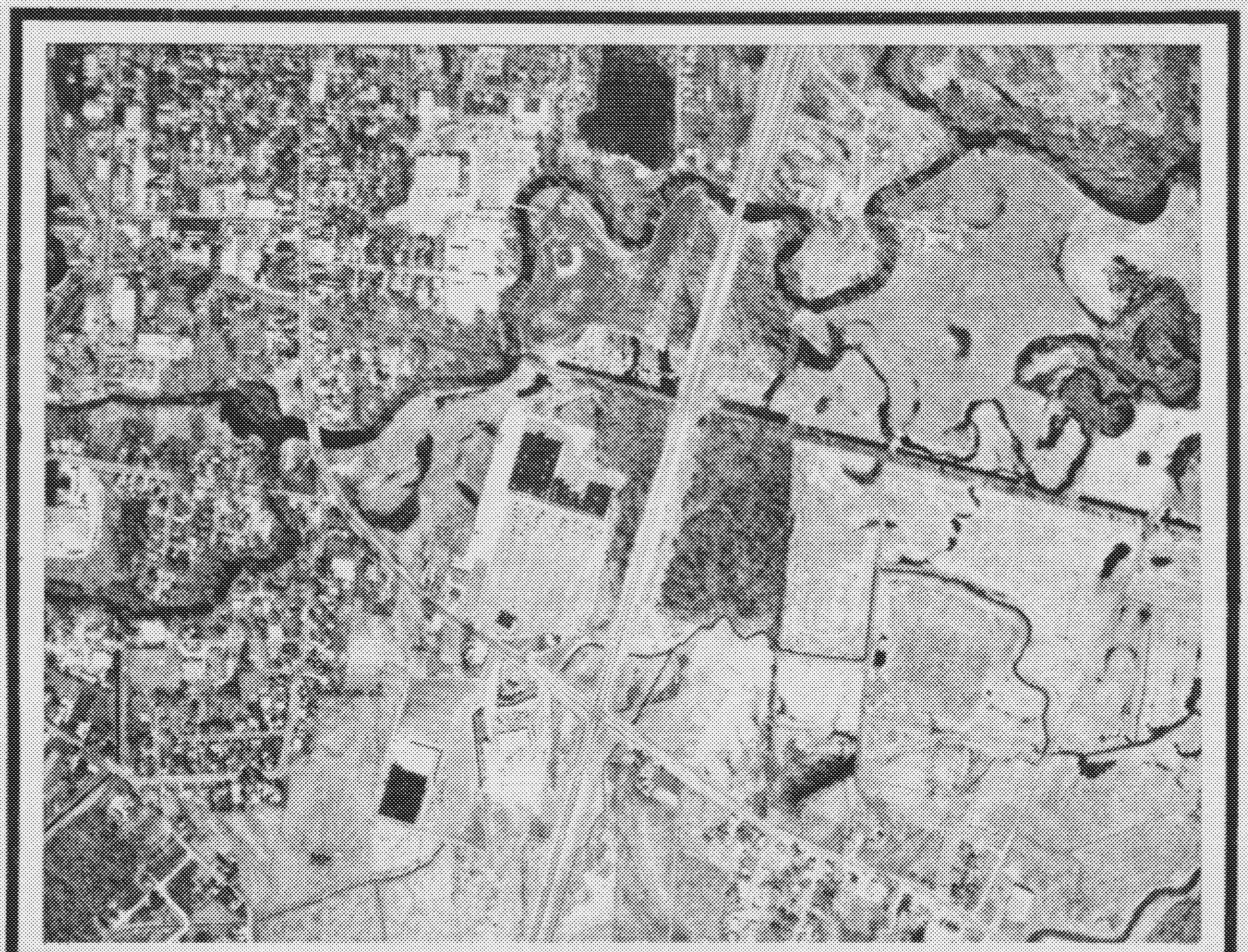
FLOOD PLAIN INFORMATION

ASHUELOT RIVER

CITY OF KEENE, NEW HAMPSHIRE



PREPARED FOR THE TOWN OF KEENE, BY THE DEPARTMENT OF THE ARMY, NEW ENGLAND DIVISION CORPS OF ENGINEERS, WALTHAM, MASSACHUSETTS.

DECEMBER 1972

FPI ASHUELOT RIVER, KEENE, N.H.

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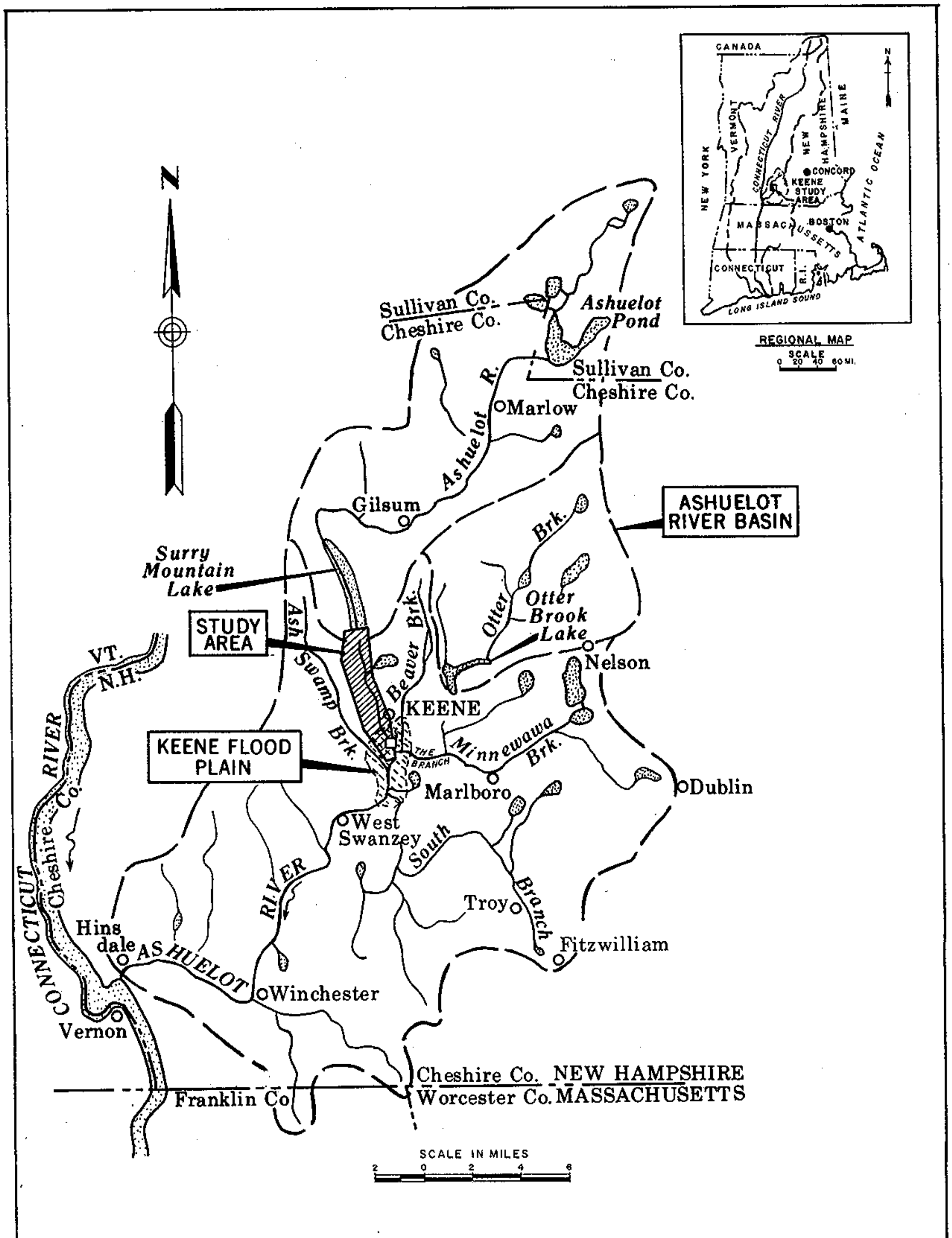


LEGEND

KEENE TELEMARK GAGE

FLOOD PLAIN INFORMATION

ASHUELOT RIVER

BASIN MAP

DECEMBER 1972

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 1

PREFACE

The portion of the city of Keene covered by this report is subject to flooding from the Ashuelot River. The properties along this stream are manufacturing, commercial and residential and have been severely damaged by the floods of 1927, 1936, 1938, and 1960. The open spaces in the flood plains which are now, or may come under pressure for future development are extensive. Large floods have occurred in the past, and studies indicate that future flooding is possible.

This report has been prepared because a knowledge of flood potential and flood hazards is important in land use planning and for management decisions concerning flood plain utilization. It includes a history of flooding in Keene and identifies those areas that are subject to possible future floods. Special emphasis is given to these floods through maps, photographs, and profiles. The report does not provide solutions to flood problems; however, it does furnish a suitable basis for the adoption of land use controls to guide flood plain development and thereby prevent intensification of the loss problems. It will also aid in the identification of other flood damage reduction techniques such as works to modify flooding and adjustments, including flood proofing, which might be embodied in an overall Flood Plain Management (FPM) program. Other FPM program studies--those of environmental attributes and the current and future land use role of the flood plain as part of its surroundings--would also profit from this information.

At the request of the city of Keene and endorsement of the New Hampshire Water Resources Board, this report was prepared by the Corps of Engineers, New England Division, under continuing authority provided in Section 206 of the 1960 Flood Control Act, as amended.

Assistance and cooperation of the U.S. Geological Survey, the State of New Hampshire, the city of Keene, and private citizens in supplying useful data and photographs for the preparation of this report are appreciated.

Additional copies of this report can be obtained from the city of Keene. The Corps of Engineers, New England Division, upon request, will provide technical assistance to planning agencies in the interpretation and use of the data presented as well as planning guidance and further assistance, including the development of additional technical information.

BACKGROUND INFORMATION

Settlement

The first permanent settlement at Keene was founded in 1750 following an earlier attempt at settlement in the 1730's that was abandoned after experiencing a series of attacks by hostile Indians. This was the first permanent settlement in the New Hampshire - Vermont area of the Connecticut River basin. Keene was chartered as a town in 1753 and incorporated as a city in 1874. At the time of settlement, the major source of livelihood for the population was agriculture. However, as more settlements were established throughout the area, Keene became the market and industrial center for the area. Much of the early industrial development took place along the streams so that the new industries could use water as a source of power. Today, Keene is the county seat for Cheshire County and the economic center for the Ashuelot River watershed.

The Stream and Its Valley

The Ashuelot River watershed is located in the southwest corner of New Hampshire in Sullivan and Cheshire Counties, with a small section in north-central Massachusetts in Franklin County. The watershed is diamond shaped and has a length of 42 miles and a width of 17 miles (see Plate 1). The river has a total fall of 1,475 feet in its 64-mile length, most of which is concentrated near its headwaters. Generally, the watershed is hilly with low mountains in the headwaters and a few natural ponds and lakes scattered throughout the area. The terrain in the upper watershed is steep and conducive to rapid runoff above the Keene Flood Plain. The elevation of the watershed varies from 3,165 feet m.s.l. at Monadnock Mountain in the southeastern headwaters to 227 feet m.s.l. at the mouth in the southwestern portion. Outside the central city of Keene, the watershed area is sparsely populated and more noticeably rural in nature. Because of fairly heavy forests and hilly terrain, this region has not shared in the extensive recreational development in New Hampshire. Agricultural productivity is not exceptionally large.

The Ashuelot River with a total drainage area of 421-square miles is a major tributary of the Connecticut River. Rising in Millen Lake in Sullivan County, it drains portions of two New Hampshire counties and a small part of Franklin County in Massachusetts. (See Plate 1.) Above Surry Mountain Lake, the Ashuelot River flows swiftly through high bordering hills. Below Surry Mountain Lake, the fall of the river is quite gradual. From Ashuelot Pond to the toe of Surry Mountain Dam, the river falls about 940 feet in approximately 22 miles or with an average slope of about 42.7 feet per mile. From Surry Mountain Dam to West Swanzey, the river drops about 40 feet in about 16 miles with an average slope of about 2.5 feet per mile. The slope of the river through the city of Keene is negligible.

Those sections of the Ashuelot River and its main tributaries, the Branch and the South Branch, included in this study are shown on the Basin Map (Plate 1). The Ashuelot River flows through the city of Keene toward the south in a meandering and winding fashion. The Branch, with a drainage area of 100-square miles, flows generally toward the west and empties into the Ashuelot River about 1.6 miles below the Faulkner & Colony Dam and about 0.4 mile above the southerly limit of Keene and is formed by the confluence of Minnewawa and Otter Brooks. Beaver Brook, which flows in a general north to south direction through heavily built-up areas of Keene, is a tributary of the Branch and joins it just above its confluence with the Ashuelot River. The South Branch, with a drainage area of 72-square miles flows in a northwesterly direction and then southwesterly and joins the Ashuelot River in the town of Swanzey, New Hampshire, about 4 miles below Faulkner & Colony Dam and 2 miles below the city limit of Keene. Drainage areas contributing to runoff at location in or near the study area are shown in Table 1.

Discharges from the Ashuelot River and the two main tributaries converge in a flood plain known as the Keene Flood Plain, which has as its limits, the Faulkner & Colony Dam, upstream, above West Street in the city of Keene and the Dickinson Dam in West Swanzey. That part of the Keene Flood Plain, from the Faulkner & Colony Dam to the mouth of the Branch, a distance of about 1.6 miles, is the critical flood damage area in the city of Keene. Approximately 75 percent of the Ashuelot River drainage area empties into the Keene Flood Plain. The meandering river channel in the Plain has low discharge capacity due to its small cross-sectional area and flat gradients with the result that floodwaters cause considerable depth of ponding in the Plain. Outflow from the Plain is a function of the depth of ponding.

TABLE 1
DRAINAGE AREAS IN ASHUELOT RIVER WATERSHED

Stream	Location	Miles Above Mouth of Ashuelot R.	Drainage Area sq. mi.
Ashuelot River	Mouth	0.0	421
	USGS Gage at Hinsdale, N.H.	1.3	420
	Above South Branch	23.3	236
	Lower City Limit, Keene, N.H. (Lower Limits of Study)	25.2	215
	Above the Branch	25.8	114
	USGS Gage below Surry Mountain Dam	34.0	101
	Surry Mountain Dam (Upper Limit of Study)	34.1	100
	USGS Gage at Webb, N.H.	43.4	71.1
South Branch	Mouth	23.3	72
	USGS Gage at Webb, N.H.	-	36
Ash Swamp Brook	Mouth	24.9	18
The Branch	Mouth	25.8	100
Beaver Brook	At the Branch	-	10
Otter Brook	Mouth	-	55
	USGS Gage below Otter Brook Dam	-	47.2
	At Otter Brook Dam	-	47
Minnewawa Brook	Mouth	-	33

The watershed has a variable climate characterized by frequent but generally short periods of heavy precipitation. It lies in the path of the "prevailing westerlies" and is exposed to the cyclonic disturbances that cross the country from the west or southwest. The area is also subject to coastal storms that travel up the Atlantic seaboard in the form of hurricanes of tropical origin and storms of extra-tropical nature, often called "northeasters." The winters are moderately severe with subzero temperatures quite common. The spring melting of the winter snow cover occurs generally in late March or April.

The mean annual temperature at Keene is approximately 45° F. with the average monthly temperature varying from about 70° F. in July to near 20° F. in January. Extremes in temperature range from highs slightly in excess of 100° F. to lows in the minus thirties.

Developments in the Flood Plain

The flood plain of the Ashuelot River is quite extensive within the city of Keene. Of necessity, because of the location of the city, much development has taken place in the flood plain and includes residential, commercial, and industrial installations. Railroads, highways, streets, utility lines and production facilities are subject to flooding.

The economy of the watershed area is stable and highly industrialized. According to the 1970 census, the city of Keene has a population in excess of 20,000, almost one-half the population of the watershed area. Keene is the fifth largest municipality in the state and the economic center of the watershed. Population trends for the watershed and the state are shown below:

	1940	1950	1960	1970
Ashuelot Basin	28,500	31,900	35,400	41,750
New Hampshire	491,520	533,240	606,920	722,750

Population increases indicate that further development will take place in the flood plain in the city of Keene. Among the more recent developments in the flood plain is a low income housing for the elderly complex in the upper reach of the study between the Faulkner & Colony Dam and the northern city limit of Keene. There is another housing project located in the flood plain off Winchester Street. Large shopping centers have been developed on both sides of Winchester Street near the Keene bypass. Keene State College has constructed new buildings on the left bank of the river. The college has also constructed an athletic field which, like the golf course constructed in the upper reach of the study, just below Surry Mountain Lake, constitutes wise use of the flood plain.

FLOOD SITUATION

Sources of Data and Records

The U.S. Geological Survey has several gaging stations in the Ashuelot River watershed. These gages are listed in Table 2. Also, the Corps of Engineers has a telemark gage on the Ashuelot River near the sewage pumping station in Keene. This gage is the principal index point for the Keene Flood Plain because of its sensitive location on the river, just above the confluence with the Branch. It is also the prime indicator for operating Surry Mountain and Otter Brook flood control dams (see Plate 1).

The Corps of Engineers has been collecting information for many years on existing and prospective flood conditions and hazards in the vicinity of Keene, New Hampshire. Investigations were made following all of the significant floods which have occurred in the area since and including that of March 1936. Information such as high watermarks has been obtained by interviewing local residents through the years and making field investigations. In addition, newspaper files, historical documents and records were searched for information concerning past floods. These records have developed a knowledge of floods which have occurred on the Ashuelot River in Keene.

Maps prepared for this report were based on U.S. Geological Survey quadrangle sheet entitled, "Keene, N.H. - Vt.," dated 1958. Data on future flood depths in existing developments were obtained from field surveys performed by the Corps of Engineers, New England Division personnel.

Flood Season and Flood Characteristics

The main flood season for the Ashuelot River is in the spring, usually resulting from rains combined with melting snow, which was characteristic of the great March 1936 flood. However, two of the greatest floods (November 1927 and September 1938) occurred in the fall and were due entirely to rainfall. In addition, severe local thunderstorms can cause flash floods on the tributaries. Floods can occur in the Keene Flood Plain in any month of the year.

TABLE 2
LOCATION OF GAGING STATIONS
Ashuelot River Watershed

Location	Records Available From
Otter Brook, Near Keene	Oct 1923 to May 1958
Otter Brook, Below Lake	May 1958 " Date
South Branch, Ashuelot River at Webb, N.H. ...	Oct 1920 " "
Ashuelot River, Near Gilsum, N.H.	Aug 1922 " "
Ashuelot River, Below Surry Mountain Lake	Sep 1945 " "
Ashuelot River, Near Hinsdale, N.H.	Mar 1907 " "

Miscellaneous Stations

Island Street Staff Gage on Ashuelot River, Keene, N.H.
Keene Telemark Gage on Ashuelot River, Keene, N.H.

Factors Affecting Flooding and Its Impact

Obstructions to floodflows - Natural obstructions to floodflows include narrow channels as well as trees, brush and other vegetation growing along the streambanks in floodway areas. Man-made encroachments on or over the streams such as filling in the flood plains, dams, bridges, and culverts can also create more extensive flooding than would otherwise occur.

During floods, trees, brush and other vegetation growing in floodways impede floodflows, thus creating backwater and increased flood heights. Trees and other debris may be washed away and carried downstream to collect on bridges and other obstructions to flow. As floodflow increases, masses of debris break loose and a wall of water and debris surges downstream until another obstruction is encountered. Debris may collect against a bridge until the load exceeds its structural capacity and the bridge is destroyed. The limited capacity of obstructive bridges retards floodflows and results in flooding upstream, erosion around the bridge approach embankments and possibly damage to the overlying roadbed.

In general, obstructions restrict floodflows and result in overbank flows and unpredictable areas of flooding, destruction of or damage to bridges and an increased flow immediately downstream. It is impossible to predict the degree or location of the accumulation of debris, therefore, for purposes of this report it was necessary to assume that there would be no accumulation of debris to clog any of the bridge openings in the development of the flood profiles.

The Faulkner & Colony Dam has no flood control capacity nor will it seriously alter flow characteristics of floodflows.

There are several bridges spanning the Ashuelot River in Keene. In the event of an accumulation of debris, any one of the bridges could become an obstruction to floodflows. Pertinent information on all of the bridges in the study area can be found in Table 6.

Below the Faulkner & Colony Dam, on the Keene Flood Plain, velocity is not the critical factor in flood damage, so obstructions to flow are not a serious problem.

Flood damage reduction measures - There are two Corps of Engineers flood control dams in operation in the Ashuelot River watershed. Surry Mountain Lake is located on the Ashuelot River, 5 miles north of Keene. The dam, completed in June 1942, is of rolled-earthfill with a dumped rock shell 86 feet high and 1,670 feet long. The reservoir is operated for flood control purposes and has a storage capacity of 32,500 acre-feet, which is equivalent to 6.1 inches of runoff from its drainage area of 100 square miles. Otter Brook Lake, completed in August 1958, is located on Otter Brook. The site is about 4.9 miles above the confluence of The Branch with the Ashuelot River. The project is a rolled-earthfill dam 133 feet high and 1,288 feet long. It is operated for flood control purposes and has a flood storage capacity of 17,600 acre-feet, equivalent to 7.0 inches of runoff from the drainage area of 47 square miles. The Keene local protection project, completed in August 1954, is located along the Ashuelot River from the railroad bridge in Keene to the covered bridge at Swanzey Station. This improvement improves the functioning of the drainage and sewerage systems and increases the usability of farmlands located along the river. The City of Keene is responsible for operation and maintenance.

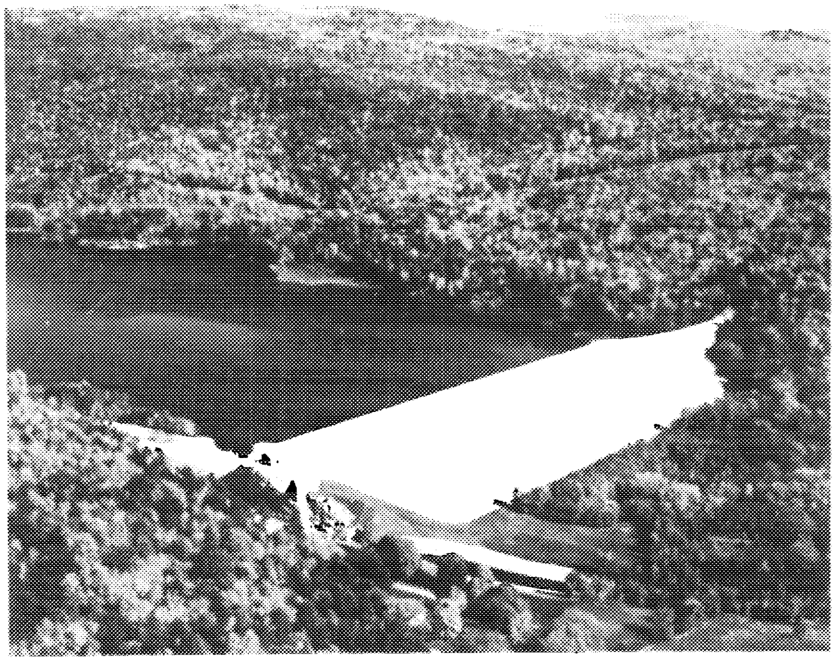


Figure 1 - Surry Mountain Lake

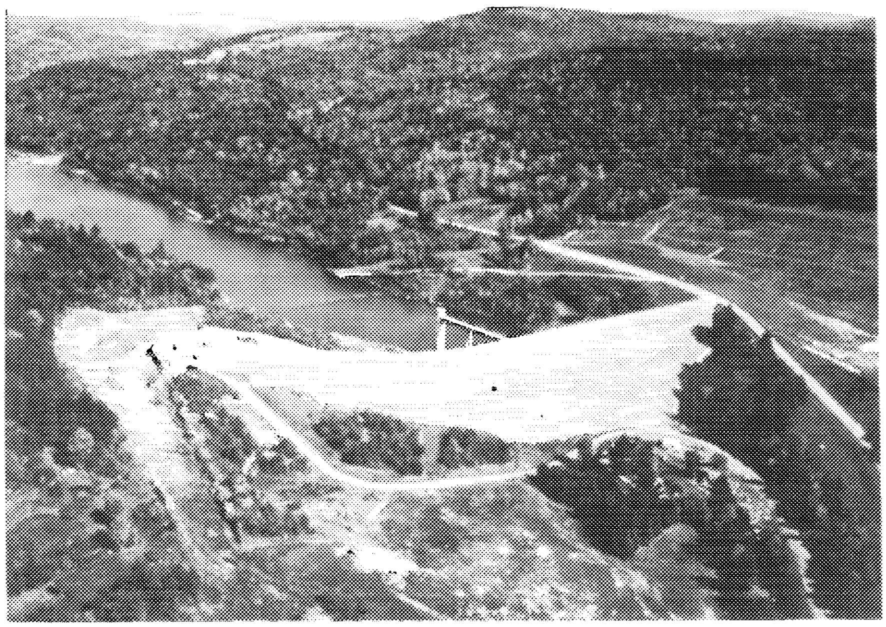


Figure 2 - Otter Brook Lake

Other factors and their impacts - The major damage center in the study area is along the lower reach, on the Keene Flood Plain. During a flood, water ponds on the flood plain and the area remains inundated for several days, thus causing a great deal of damage.

Flood warning and forecasting - The U.S. Dept. of Commerce River Forecast Center at Hartford, Connecticut is responsible for issuing flood warnings for the protection of life and property in the Connecticut River basin. The flood warnings are issued by teletype simultaneously to the press service, State Police, Civil Defense and many other state and local agencies.

A flood warning system is only one phase of preventative flood damage measures. The other phase is the preparation of Federal and local governments and private citizens to combat the impending storm. Without a sufficient storm warning and an ability to react to the warning, the residences, industrial and commercial establishments in low-lying areas will be defenseless against the flood waters of the Ashuelot River.

Flood fighting and emergency evacuation plans - There are no formal plans for food fighting and emergency evacuation in Keene. These activities are considered to be functions of Civil Defense, which is under the direction of the fire chief. Informal arrangements have been made whereby the fire chief would coordinate the functions of all public and private organizations during a flood emergency.

Material storage on the flood plain - At the present time there is a considerable amount of material stored on flood plain lands along the Ashuelot River and consists mostly of lumber and some lightweight containers and empty tanks. This material might be carried away by floodwaters and cause more damage by creating additional restrictions during a flood.

PAST FLOODS

Summary of Historical Floods

Damaging floods have been reported to have occurred in the Keene area as early as 1738. Floods causing significant damage are described to have occurred in 1738, 1801, 1807, 1813, 1818, 1824, 1828, 1841, 1862, 1869, 1882, 1895, 1897, 1900, 1927, 1936, 1938, 1960, and 1969. Among these, the March 1936 flood was the largest on record on the Ashuelot, with the September 1938 flood being almost as large. Little data are available on floods prior to 1900, however, the flood of October 1869 probably caused the most damage of any of these earlier floods.

Flood Records

Table 3 lists the stages and discharges at the U.S. Geological Survey gage located at Hinsdale, N.H. for the ten highest floods which have occurred on the Ashuelot River in recent years. The Hinsdale gage is the only gage located downstream of the study area.

TABLE 3
HIGHEST TEN KNOWN FLOODS
Ashuelot River at Hinsdale, N. H.

Order No.	Date of Crest	Gage Height Stage ft	Gage Height Elevation(a) ft msl	Estimated Peak Discharge cfs
1	March 19, 1936	20.2(b)	221.5	16,600
2	September 22, 1938	11.4	212.7	16,200
3	November 5, 1927	13.4(b)	214.7	13,400
4	March 29, 1920	8.1	209.4	9,550
5	April 7, 1923	7.9	209.2	8,940
6	April 5, 1960	8.9	210.2	8,800
7	April 14, 1940	8.6	209.9	8,650
8	April 14, 1934	8.1	209.4	8,380
9	March 14, 1936	8.1	209.4	8,360
10	April 19, 1933	7.7	209.0	8,180

(a) Keene datum is 5.3 feet above mean sea level.
(b) Gage heights affected by backwater from Connecticut River.

Flood Descriptions

The following are descriptions of known large floods that have occurred in the vicinity of Keene, New Hampshire:

OCTOBER 1869

There are no accurate records of the October 1869 flood; however, the following extract from the "New Hampshire Sentinel," Keene, N. H. gives an account of the flood:

> "The destruction of property was immense, and we have seen the loss estimated as high as one hundred millions of dollars in New England alone. No spring freshets ever began to do such damage.
>
> It was so sudden and unexpected that no precautions could have been taken, and none were. Railroads, telegraph wires, streets, bridges, dams, manufactories, houses, lands, crops, have been utterly or partially ruined over this wide extent of country; and such an embargo on travel has not been seen before since railroads were, etc., etc."

NOVEMBER 1927

The November 1927 flood, the third largest in the Ashuelot basin, resulted from rainfall of 4 to 5 inches falling on ground saturated from excessive rains during the previous month.

> "Files of the 'New Hampshire Sentinel,' dated October 11, 1869, show conclusively that property loss, both personal and public, as well as deaths were greatly in excess that year (1927) than when a flood swept over this section of the country 58 years ago (1869). It will be noticed that the flood apparently followed the same course as the one now in progress and that damage was done in about the same sections."

MARCH 1936

The flood of March 1936 is the greatest volume flood of record in the Ashuelot River basin. This flood resulted from two major rainstorms which, combined with heavy snowmelt, caused two major rises in river stages only six days apart. The stage at the telemark gage rose to elevation 473.4 ft. m.s.l. (478.7 ft. Keene datum). Modification of this flood by Surry Mountain and Otter Brook Lakes would have resulted in a reduced peak elevation of 470.7 ft. m.s.l. (476.0 ft. Keene datum) or a reduction of 2.7 feet in the stage at the telemark gage.

SEPTEMBER 1938

The flood of September 1938, the greatest peaking flood of record for the Ashuelot River watershed, occurred when a hurricane passed over the watershed. Rainfall accompanying the hurricane over the basin, combined with precipitation of the previous three days, totaled over 10 inches. The maximum peak reached an elevation of 475.3 ft. m.s.l. (480.6 ft. Keene datum) at the telemark gage in Keene. Surry Mountain and Otter Brook Lakes would have reduced the peak elevation to 471.7 ft. m.s.l. (477.0 ft. Keene datum) which is a reduction of 3.6 feet in the stage at the telemark gage.

APRIL 1960

The flood of April 1960 ranks sixth among the ten highest most recent floods in the Ashuelot River watershed as recorded at the U.S. Geological Survey gage at Hinsdale, N.H. This flood occurred when a total of 3 to 4 inches of rain fell on snow with a high water content. Maximum stage reached at the telemark gage in Keene was elevation 468.3 ft. m.s.l. (473.6 ft. Keene datum).

APRIL 1969

Stages for this event were the result of cumulative runoff from snowmelt over most of the month of April combined with sporadic rainfall. Maximum stage reached at the telemark gage in Keene was elevation 467.4 ft. m.s.l. (472.7 ft. Keene datum).

Figure 3 - Faulkner & Colony Dam during March 1936 flood (dam is directly under covered bridge).

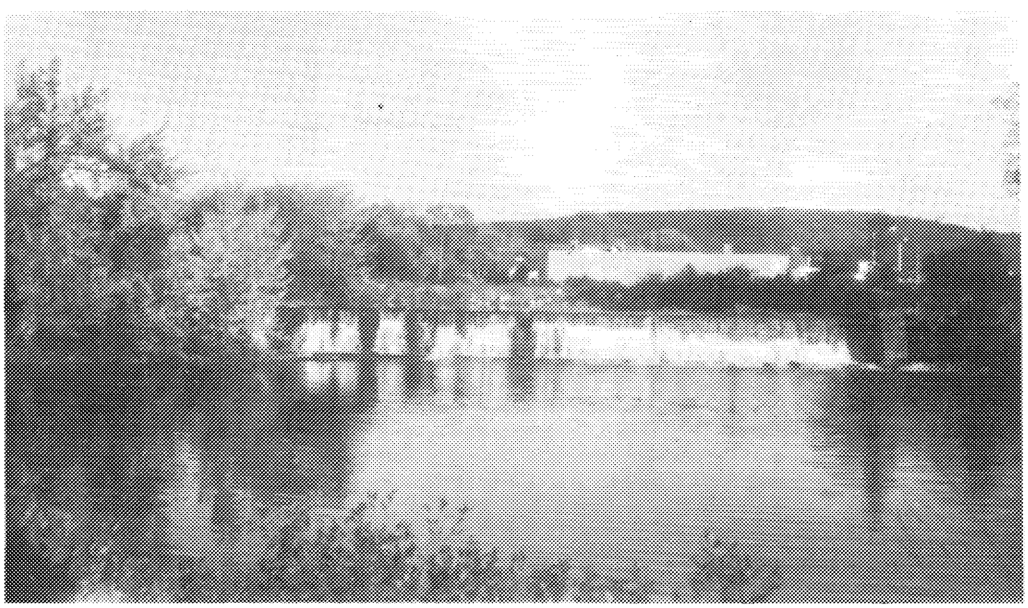


Figure 4 - Faulkner & Colony Dam during normal flow, October 1970 (Note: Covered bridge has been removed).

Figure 5 - West Street looking east toward intersection with Ashuelot Street during flood of March 19, 1936.

Figure 6 - Same view as above on next day, March 20, 1936, showing damage to roadway caused by flooding.

Figure 7 - Corner of River and Castle Streets looking west toward intersection of Castle and Ashuelot Streets during flood of March 1936.

Figure 8 - Ashuelot Street looking south from the intersection of Castle Street, March 18, 1936.

FUTURE FLOODS

Floods of the same or larger magnitude as those that have occurred in the past could occur in the future. Larger floods have been experienced in the past on streams with similar geographical and physiographical characteristics as those found in the study area. Similar combinations of rainfall and runoff which caused these floods could occur in the Keene area. Therefore, to determine the flooding potential of the study area, it was necessary to consider storms and floods that have occurred in regions of like topography, watershed cover and physical characteristics. Discussion of the future floods in this report is limited to those that have been designated as the Intermediate Regional Flood (IRF) and the Standard Project Flood (SPF). The Standard Project Flood represents a reasonable upper limit of expected flooding in the study area. The Intermediate Regional Flood may reasonably be expected to occur more frequently although it will not be as severe as the infrequent Standard Project Flood.

Intermediate Regional Flood

The Intermediate Regional Flood is defined as one that could occur once in 100 years on the average, although it could occur in any year. It might be better described as a flood with a 1% chance of occurring each year. The peak flow of this flood was developed from statistical analysis of streamflow and precipitation records and runoff characteristics for the stream under study. In determining the Intermediate Regional Flood statistical studies were made using the more than 60 years of records of known flood data for the Ashuelot River, and assuming that Surry Mountain and Otter Brook Lakes would be operating.

Results of the studies indicate that the Intermediate Regional Flood would have a peak inflow to the Keene Flood Plain of 18,800 cubic feet per second and would be equivalent to the flood of September 1938 modified by the effects of Otter Brook and Surry Mountain Lakes. Discharge from Surry Mountain Lake for this flood would reach 2,000 c.f.s., or about 67% greater than the normal maximum release of 1,200 c.f.s., which was experienced during the flood of April 1960.

Modified peak flows of the September 1938 and the Intermediate Regional Flood at three significant points on the Ashuelot River at or in the vicinity of Keene are given in Table 4 for comparison purposes.

Standard Project Flood

The Standard Project Flood is defined as a major flood that can be expected to occur from a severe combination of meteorological and hydrological conditions that is considered reasonably characteristic of the geographical area in which the study area is located, excluding extremely rare conditions. The Corps of Engineers, in cooperation with the NOAA Weather Service, has made comprehensive studies and investigations based on the past records of experienced storms and floods and has developed generalized procedures for estimating the flood potential of streams. These procedures have been used in determining the Standard Project Flood, assuming Surry Mountain and Otter Brook Lakes to be in operation.

The Standard Project Flood would have a peak inflow to the Keene Flood Plain of 22,000 c.f.s., or about 17% greater inflow than the record flood of September 1938, modified by the effects of Surry Mountain and Otter Brook Lakes. Discharge from Surry Mountain Lake would reach about 2,500 c.f.s., or somewhat greater than twice the normal maximum release of 1,200 c.f.s., which was experienced during the flood of April 1960.

Modified peak flows from the September 1938 and the Standard Project Flood at three significant points at or in the vicinity of Keene are given in Table 4 for comparison purposes. The relative water surface elevations for the Intermediate Regional Flood and the Standard Project Flood are shown in Plate 3.

TABLE 4
PEAK FLOWS FOR INTERMEDIATE REGIONAL AND STANDARD PROJECT FLOODS

Location	(Peak Flow (c.f.s.)) (a)		
	Sept. 1938 Flood	IRF	SPF
Surry Mountain Lake (Discharge)	1,200	2,000	2,500
Keene Flood Plain (Inflow)	18,800	18,800	22,000
Keene Flood Plain (Outflow at West Swanzey Outlet)	10,300	10,300	11,800

(a) Modified by the effects of Surry Mountain and Otter Brook Lakes.

Estimated inflow to the Keene Flood Plain for the September 1938 flood was 31,200 c.f.s. This record inflow to the Flood Plain does not reflect the present reductions as a result of the completed Surry Mountain and Otter Brook Lakes. A recurring September 1938 flood with the above lakes in place would result in an inflow of 18,800 c.f.s., which would be approximately one foot lower than the SPF and about the same elevation as the IRF. A flood comparison between the experienced September 1938, the modified September 1938, the Intermediate Regional and the Standard Project Floods are shown at the telemark gage near the sewage pumping station (see Table 5).

TABLE 5
FLOOD ELEVATION
(Telemark Gage near Sewage Pumping Station)

Flood	Elevation	
	ft msl	ft Keene Datum
Standard Project	472.7	478.0
Intermediate Regional	471.7	477.0
Sept. 21, 1938 (Natural)	475.3	480.6
Sept. 21, 1938 (Modified)	471.7	477.0

Frequency

A frequency curve of peak flows in the Ashuelot River basin was constructed on the basis of available information and computed flows of floods up to the magnitude of the Standard Project Flood. The frequency curve thus derived, which is available on request, reflects the judgment of engineers who have studied the area and are familiar with the region; however, it must be regarded as approximate and should be used with caution in connection with any planning of flood plain use. Floods larger than the Standard Project Flood are possible but the combinations of factors necessary to produce such large flows would be extremely rare.

Hazards of Large Floods

The extent of damage caused by any flood depends on the topography of the area flooded, depth and duration of flooding, velocity of flow, rate of rise, and developments in the flood plain. An Intermediate Regional or Standard Project Flood on the Ashuelot River would result in inundation of residential and commercial sections in the Keene area. Deep floodwater carrying floating debris would create conditions hazardous to persons and vehicles attempting to cross flooded areas. In general, floodwater 3 or more feet deep and flowing at a velocity of 3 or more feet per second could easily sweep an adult person off his feet, thus creating definite danger of injury or drowning. Rapidly rising and swiftly flowing floodwater may trap persons in homes that are ultimately destroyed, or in vehicles that are ultimately submerged or floated. Water lines can be ruptured by deposits of debris and the force of floodwaters, thus creating the possibility of contaminated domestic water supplies. Damaged sanitary sewer lines and sewage treatment plants could result in the pollution of floodwaters creating health hazards. Isolation of areas by floodwater could create hazards in terms of medical, fire, or law enforcement emergencies.

Flooded areas and flood damages - The areas in the city of Keene that would be flooded by the Standard Project Flood are shown on Plate 2. The actual limits of these overflow areas may vary somewhat from those shown on the map because the contour interval and scale of the map do not permit precise plotting of the flooded area boundaries. To determine if an area would be in the flooded area, the elevation of the area should be determined and compared against the profile shown on Plate 3. Although there would be some flood damages upstream of the Faulkner & Colony Dam, the greatest amount of flood damage would be on the Keene Flood Plain below the Faulkner & Colony Dam. Floodwaters would inundate the flood plain and remain high for several days during a large flood. Even though some of the buildings are built above the flood level, access to them may be impossible due to flooded roads in the area. Even though the areas inundated by floodwaters would suffer the greatest losses, the entire city would feel the effects of a flood in several ways. There would be the direct cost of emergency relief in addition to indirect losses such as loss of utilities due to flooding of underground conduits and possible flooding of the electrical substation and gas company yard on Emerald Street. The city would be subject to a serious health hazard if the sewage pumping station on Martell Court were to be flooded. There is also the possibility that many people would be out of work if the many businesses in the flooded area were to be closed due to flood damages. In general, flooding along the Ashuelot River in Keene would affect the whole city, either directly or indirectly.

Obstructions - During floods, debris collecting on bridges could decrease their carrying capacity and cause greater water depths (backwater effect) upstream of these structures. Since the occurrence and amount of debris are indeterminate factors, only the physical characteristics of the structures were considered in preparing profiles of the Intermediate Regional and Standard Project Floods. Similarly, the maps of flooded areas do not reflect increased water surface elevation that could be caused by debris collecting against the structures. The Faulkner & Colony Dam (the only one within the study area) has no flood control capacity, nor does it seriously alter flow characteristics of floodflows.

None of the bridges in the study area cause serious obstructions to floodflows. All but one of the bridges that would be inundated in the Intermediate Regional or Standard Project Floods are below the Faulkner & Colony Dam on the Keene Flood Plain. Overtopping of the bridges on the Keene Flood Plain does not cause a serious problem because flood is not a critical damage factor in that area. Above the Faulkner & Colony Dam, the bridge at the golf course would be inundated by the Standard Project Flood. However, the land around the bridge is low so some of the floodflow could go around the bridge, thus causing the bridge to be only a minor obstruction. Table 6 lists water surface elevations at bridges crossing the Ashuelot River in Keene.

Velocities of flow - Velocity is not a major flood damage factor along the Ashuelot River in Keene. High velocity flows are not associated with flooding in the Keene Flood Plain because the flooding is caused by the flat gradient and the channel restrictions downstream. Upstream of the Faulkner & Colony Dam velocity is more significant, but it causes only minor damage. Since most of the flood damage in Keene is caused by ponding rather than flow no data has been collected on velocities of flow.

Rates of rise and duration of flooding - The magnitude and rate of rise and, consequently, the duration of flooding along the Ashuelot River between Surry Mountain and Faulkner & Colony Dams is regulated to a significant degree by Surry Mountain Dam which controls approximately 88% of the drainage area above Faulkner & Colony Dam.

TABLE 6
ELEVATION DATA
Bridges Across the Ashuelot River

Identification	Mileage Above Mouth	Under-clearance Elevation ft msl (a)	Water Surface Intermediate Regional Flood ft msl (a)	Elevation Standard Project Flood ft msl (a)
Private (Martell Ct.)	25.9	471.5	472	473
State Highway Rtes. 9, 10 & 12 (Keene Bypass)	26.2	474.8	472	473
Private (Keene State College)	26.45	470.4	472	473
Boston & Maine Railroad	26.6	474.5	472	473
Winchester St.	26.8	470.7	472	473
Island St.	26.9	473.0	472	473
Boston & Maine Railroad	27.2	474.4	472	473
West St.	27.3	473.8	472	473
State Highway Route 12A (West Surry Rd.)	30.2	485.0	481	482.5
Highway (Abandoned)	30.3	484.4	481	482.5
Private (Golf Course)	32.8	487.9	487	489
Highway (E. Surry Rd.)	33.6	492.3	489.5	491.5

(a) Mean sea level is 5.3 feet below Keene datum.

The high stages in the Keene Flood Plain, from Faulkner & Colony Dam to Dickinson Dam in West Swanzey, are due to rapid runoff on the relatively steep slopes of the uncontrolled tributary streams contributing flows to the Plain. Surry Mountain and Otter Brook Lakes control about 147 square miles or 47% of the 312 square miles of drainage area contributing flow to the Keene Flood Plain.

Once maximum high water has been reached in the Keene Flood Plain, the duration of flooding is prolonged because of the great magnitude of the inundated area and the considerable depth of ponding. The large amount of detention storage on the Plain results from the low discharge capacity of the meandering river channel in the area, due to its small cross-sectional area and flat gradients.

The flood of April 1960 crested at elevation 468.3 ft. m.s.l. (473.6 ft. Keene datum) at the telemark gage and remained above elevation 472.5 ft. Keene datum, for about a day, despite no outflows from Surry Mountain and Otter Brook Lakes. During recurrences of the 1938 and 1936 events, it is estimated that the river would remain above elevation 472.5 ft. Keene datum, for five and six days, respectively. The Ashuelot River is within banks at approximately elevation 472.5 feet Keene datum.

The flood of September 1938 crested at elevation 475.3 ft. m.s.l. (480.6 ft. Keene datum) at the telemark gage and remained above elevation 472.5 ft. Keene datum, for about five days. The maximum rate of rise at the telemark was approximately 0.3 feet per hour and occurred over the period from the early evening of September 20th through the early morning of September 21st when the stage rose about 3.6 feet in 12 hours.

Photographs, future flood heights - The levels that the Intermediate Regional and Standard Project Floods are expected to reach at various locations in Keene are indicated on the following photographs:

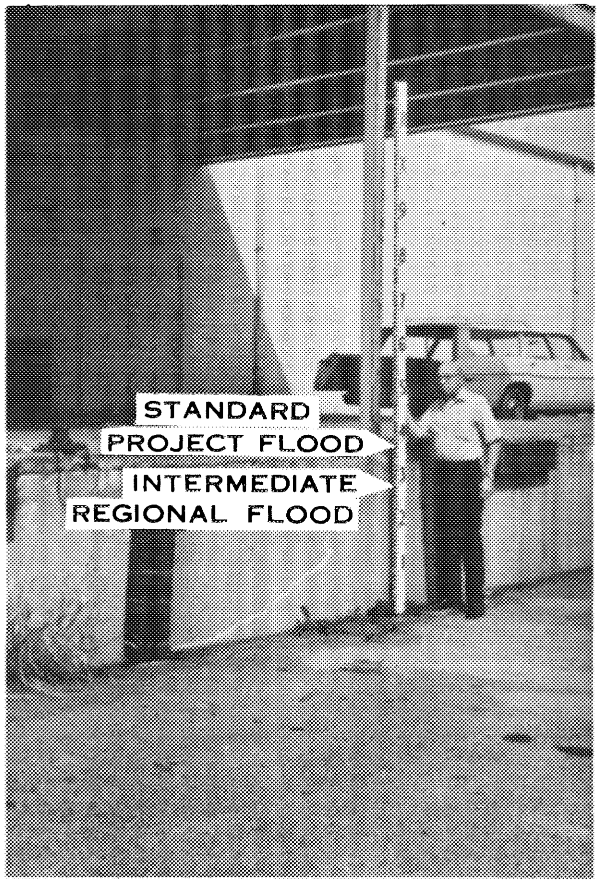


Figure 9 - Future flood heights at loading platform at rear of Grant's Department Store.

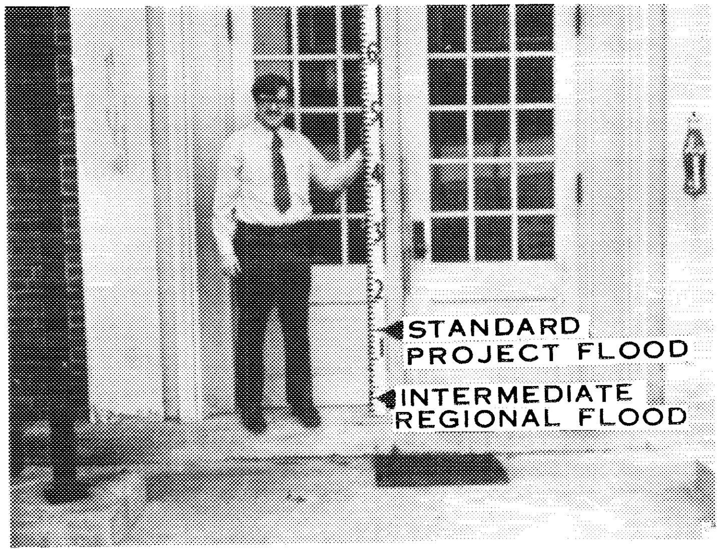


Figure 10 - Future flood heights at sewage
pumping station off Martell Court.

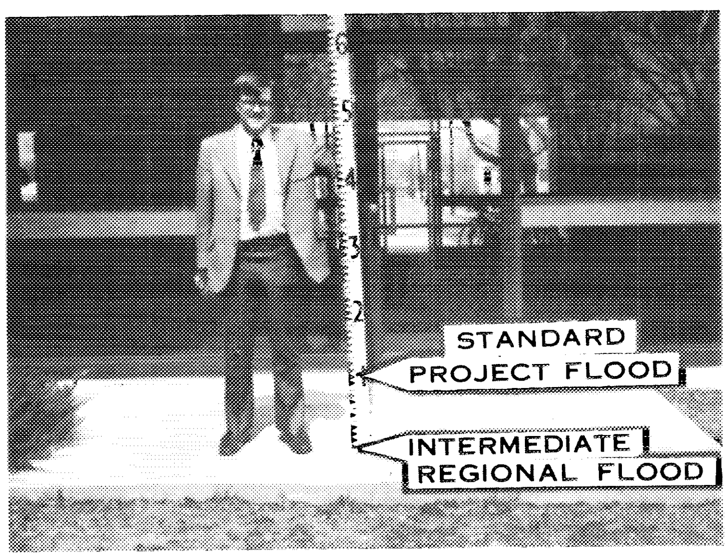


Figure 11 - Future flood heights at rear entrance
to Carle Hall, Keene State College.

GLOSSARY

Backwater. The resulting high water surface in a given stream due to a downstream obstruction or high stages in an intersecting stream.

Flood. An overflow of water onto lands not normally covered by water and that are used or usable by man. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river or stream or an ocean, lake, or other body of standing water.

Normally a "flood" is considered as any temporary rise in streamflow or stage, but not the ponding of surface water that results in significant adverse effects in the vicinity. Adverse effects may include damages from overflow of land areas, temporary backwater effects in sewers and local drainage channels, creation of unsanitary conditions or other unfavorable situations by deposition of materials in stream channels during flood recessions, rise of ground water coincident with increased streamflow, and other problems.

Flood Crest. The maximum stage or elevation reached by the waters of a flood at a given location.

Flood Hydrograph. A graph showing the stage in feet against time at a given point and the rate of rise and duration above flood stage.

Flood Plain. The areas adjoining a river, stream, watercourse, ocean, lake, or other body of standing water, which has been or may be covered by floodwater.

Flood Profile. A graph showing the relationship of water surface elevation to location, the latter generally expressed as distance above mouth for a stream of water flowing in an open channel. It is generally drawn to show surface elevation for the crest of a specific flood, but may be prepared for conditions at a given time or stage.

Flood Stage. The stage or elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

Hurricane. An intense cyclonic windstorm of tropical origin in which winds tend to spiral inward in a counterclockwise direction toward a core of low pressure with maximum surface wind velocities or longer at some points. Tropical storm is the term applied if maximum winds are less than 75 miles per hour.

Intermediate Regional Flood. A flood having an average frequency of occurrence in the order of once in 100 years although the flood may occur in any year. It is based on statistical analyses of streamflow records available for the watershed and analyses of rainfall and runoff characteristics in the "general region of the watershed."

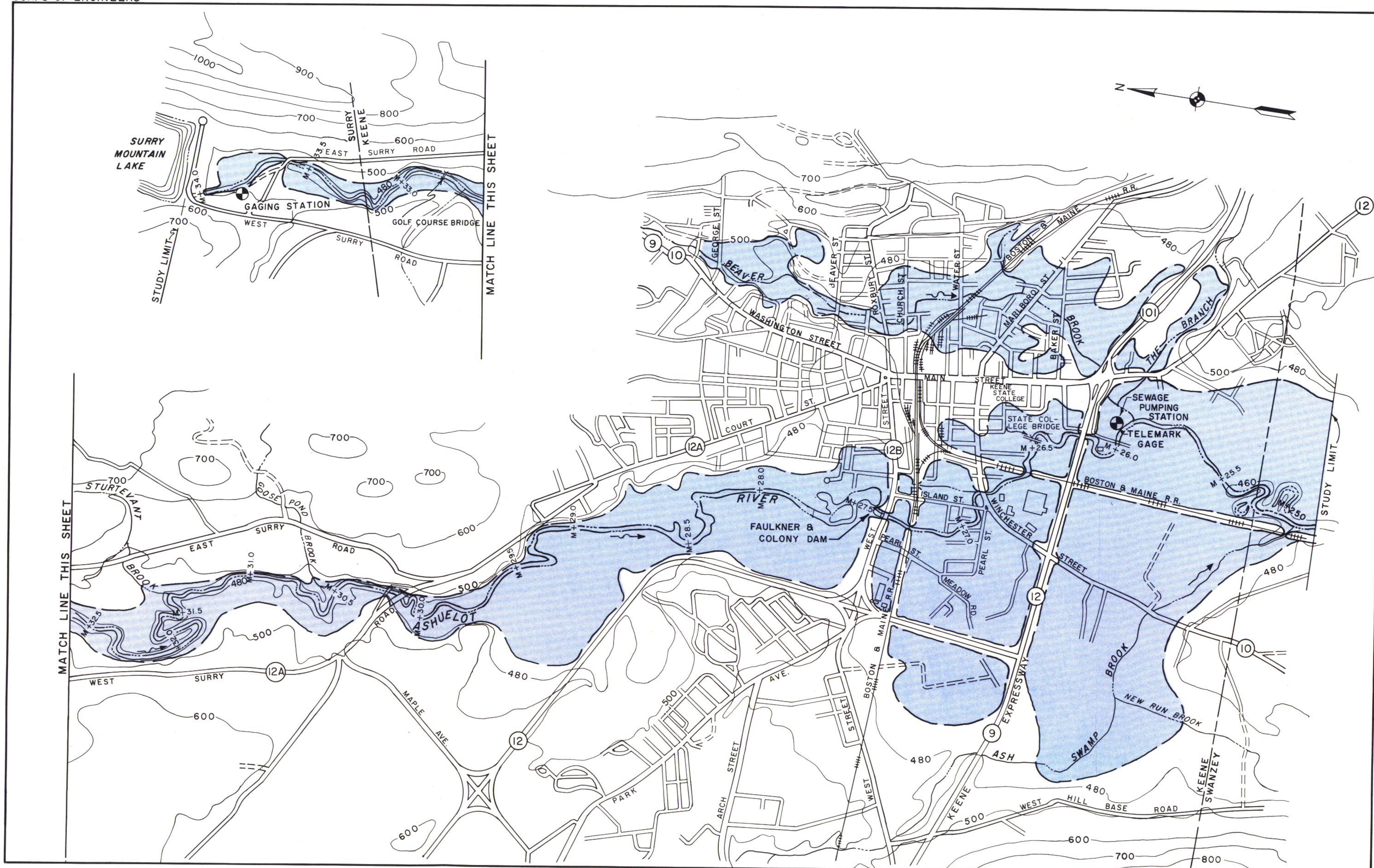
Left Bank. The bank on the left side of a river, stream or watercourse looking downstream.

Probable Maximum Flood. A hypothetical flood representing the most severe flood with respect to volume, concentration of runoff and peak discharge that may be expected from a combination of the most severe meteorological and hydrological conditions in the region.

Right Bank. The bank on the right side of a river, stream or watercourse looking downstream.

Standard Project Flood. The flood that may be expected from the more severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. Peak discharges for these floods are generally about 40% to 60% of the Probable Maximum Floods for the same basins. Such floods, as used by the Corps of Engineers, are intended as practicable expressions of the degree of protection that should be sought in the design of flood control works, the failure of which might be disastrous.

Underclearance Elevation. The elevation at the top of the opening of a culvert or other structure through which water may flow along a watercourse. This is referred to as "low steel" in some regions.



LEGEND

OVERFLOW LIMITS

INTERMEDIATE REGIONAL FLOOD (STANDARD PROJECT FLOOD COVERS APPROXIMATELY THE SAME AREA)

M + 26 MILES ABOVE MOUTH

500 GROUND ELEVATION IN FEET (U.S. C.&G.S.) SEA LEVEL DATUM

KEENE CITY LIMITS

CHANNEL

NOTES:

1. MAP BASED ON U.S.G.S. 15 MIN. KEENE QUADRANGLE SHEET, 1958. MINOR ADDITIONS AND ADJUSTMENTS MADE BY CORPS OF ENGINEERS.
2. LIMITS OF OVERFLOW SHOWN MAY VARY FROM ACTUAL LOCATION ON GROUND AS EXPLAINED IN THE REPORT.
3. AREAS OUTSIDE THE FLOOD PLAIN MAY BE SUBJECT TO FLOODING FROM LOCAL RUNOFF.
4. MINIMUM CONTOUR INTERVAL IS 20 FT.

SCALE IN MILES

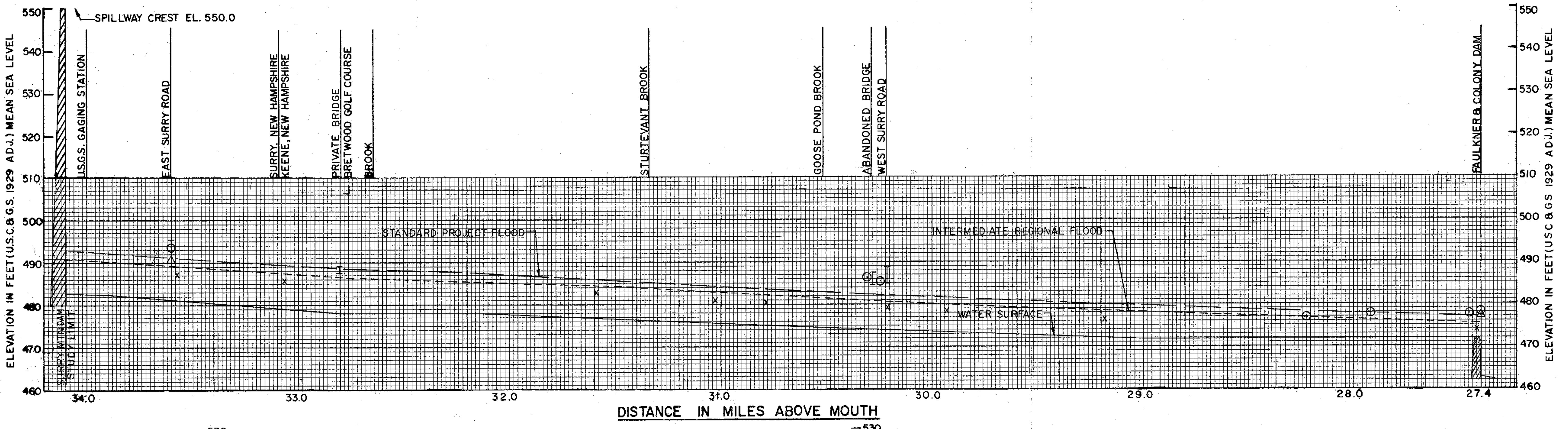
0.2 0.0 0.2 0.4

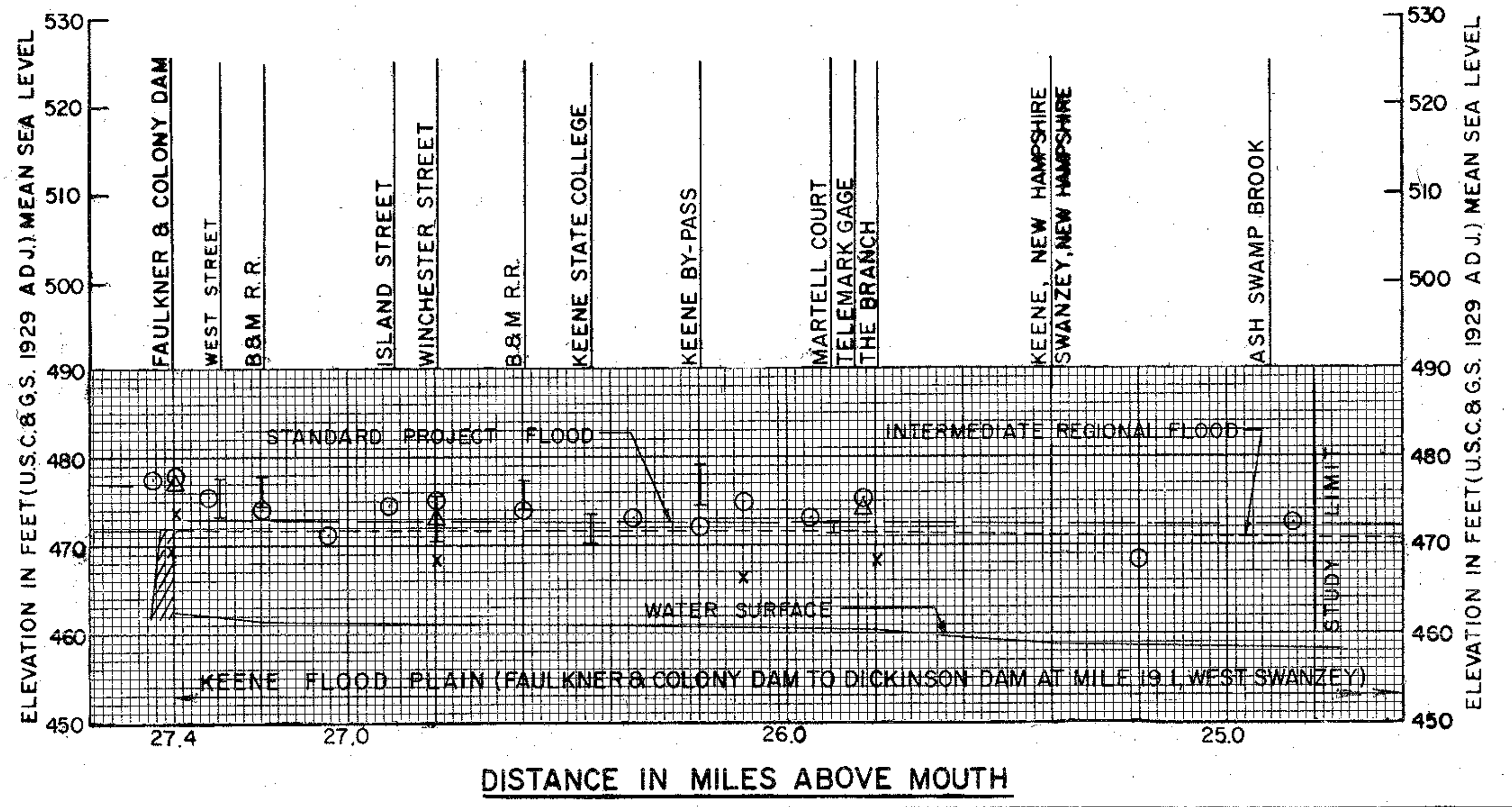
FLOOD PLAIN INFORMATION
KEENE, NEW HAMPSHIRE
ASHUELOT RIVER

FLOODED AREAS

DECEMBER 1972

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.





LEGEND

EXPERIENCED HIGH WATER
- △ MARCH 1936 FLOOD
- ○ SEPTEMBER 1938 FLOOD
- x APRIL 1960

I BRIDGE

▨ DAM

FLOOD PLAIN INFORMATION

KEENE, NEW HAMPSHIRE
ASHUELOT RIVER
FLOOD PROFILES
MILE 24.8 TO 34.1

DECEMBER 1972

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

PLATE 3